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(54) Device for treating a tree by injection

(57) A device for arboreal plant endotherapy comprises: a hollow cylinder (1) provided with a piston (2), means (3) for actuating the motion of the piston (2), at least an injection needle (41, 42, 43, 44) and means (4) for connecting the needle (41, 42, 43, 44) to the cylinder (1), to inject into the trunk of a plant at least a dose of a phytotherapeutic formulation loaded into the cylinder (1). A central processing unit (CPU) automatically and intelligently controls the device, implementing a program which comprises a procedure for determining the dose (VDOS) of formulation to be administered to a plant and a procedure to control the means (3) for actuating the motion of the piston (2) according to the dose (VDOS) to be administered. A keyboard (TT) is connected to the central unit (CPU) to enter data manually and to manage the commands of the device. An analogue digital converter (A/D), connected to the central unit (CPU) and coupled to an input interface (II), receives signals coming from a displacement sensor (5) for the detection of the position of the piston (2) in the cylinder (1). The central processing unit (CPU) controls the means (3) for actuating the motion of the piston (2) through an output interface (IU) connected thereto.

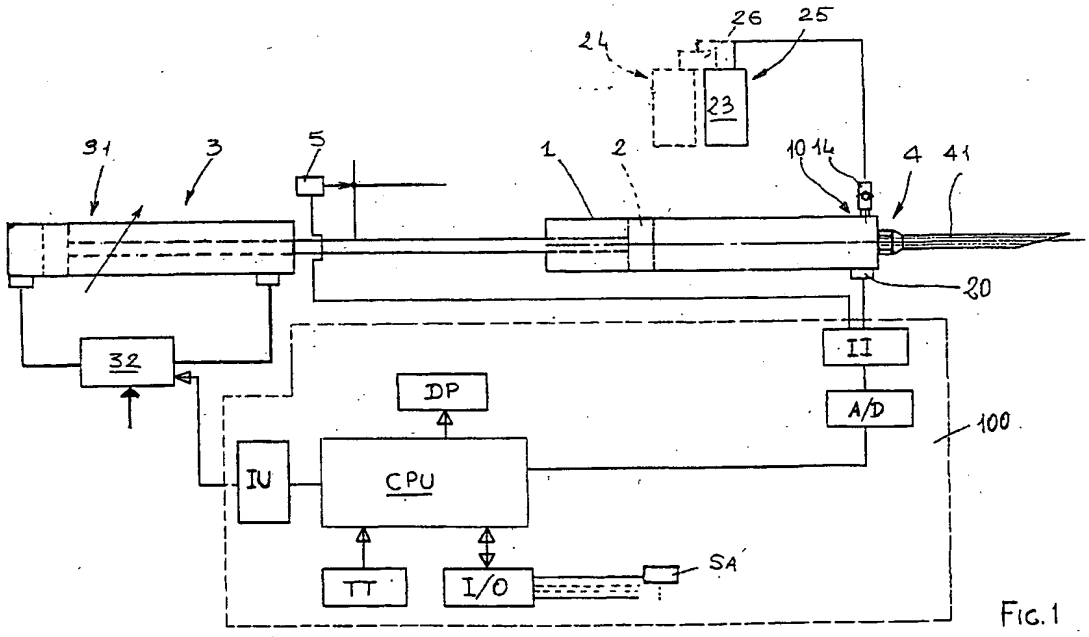

FIG. 1

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AL2

Description

[0001] The present invention relates to an endotherapy device for arboreal plants.

[0002] Endotherapy is a method for treating arboreal plants by means of phytotherapeutic formulations providing protection against parasite and/or fungal attacks, which essentially consists of injecting the phytotherapeutic formulation inside the trunk of the plant. The phytotherapeutic formulation thus injected is absorbed by the trunk of the plant and, through the lymph system of the plant, is sent into circulation and has its effect.

[0003] The use is known of actual common syringes or pumps with needle, both manually operated. By inserting the needle into one or more hole, previously obtained in the trunk of the plant, the formulation contained in the syringe or in the pump is injected (once or several times depending on the quantity of formulation required) and, at the end of the treatment, the holes are plugged with filler or putty.

[0004] These devices for arboreal plant endotherapy, also known as "simple injection" devices, have numerous drawbacks. In particular, the volumes of phytotherapeutic formulation able to be administered in each individual injection are very limited and operations are totally manual, leading to excessively long application times. The guarantee of the quality of the intervention is based solely on manual operations. Verification and control over the doses of phytotherapeutic formulation to be applied for each vegetable species and for each plant is left exclusively to the operator. There is no inter-relationship automatically structured with the outside environment or with the system constituted by the plant. Therefore, external climatic parameters and parameters within the plant (also physiological ones), which have fundamental importance to decide both the extend and the appropriateness of the endotherapeutic intervention, are not adequately taken into consideration.

[0005] Also known are arboreal plant endotherapy devices provided with graduated cylinders with internal piston, with oleo-dynamic operation activated by a pump. The pump is started or stopped manually by means of a lever. Some conduits (usually 3 or 5) connect the cylinder to an equal number of needles for injection into the trunk. The needles are inserted into holes previously obtained in the trunk by means of a drill. A certain quantity of phytotherapeutic formulation, manually determined by the operator using the graduated scale, is, at first, aspirated into the cylinder from a tank. To inject the phytotherapeutic into the trunk of the plant, the operator activates the pump in the opposite direction, and manually stops the operation of the pump when, in his/her opinion, reached by observing the graduated scale, the plant has received a correct dose of formulation.

[0006] The mechanisation of the aspiration and of the injection operations allows to handle large volumes of formulation in cylinders of considerable size.

[0007] However, this type of devices for arboreal plant endotherapy is not free from drawbacks. In particular, operating pressure, determined by the head of the pump, is neither evaluated nor controlled in any way. Therefore, there is no control over the pressure whereat the phytotherapeutic formulations are injected into the trunk of the plant and no consideration is given to the maximum physiological capacity of each individual plant to absorb a certain flow of formulation in the unit of time, with the risk of damaging the vascular tissues of the plant or to disperse the phytotherapeutic formulation externally if certain pressure values are exceeded; such values depend on the vegetable species, on the conditions and state of the plant to be treated. Operations are still all substantially manual, particularly dosage. The external environmental parameters and the characteristic parameters of the plant (in particular the physiological ones) are not taken into adequate consideration automatically, leaving the decision as to the appropriateness and conditions of the interventions completely up to the operator.

[0008] To eliminate the risk of damaging the vascular tissues of the plant with excessive injection pressures and to have a correct dosage of the phytotherapeutic formulation, endotherapy devices for arboreal plants are known in which the needles inserted into the trunk of the plant are connected, by means of corresponding conduits, to bags of the kind used for intravenous injections, so that the injection takes place through the action of gravity. The bags contain dosed quantities of formulation and the injection pressure is determined by the weight of the formulation present in the bag.

[0009] These devices also have drawbacks. In particular, the bags need to be refilled or replaced periodically, do to the sizeable volumes to be injected with respect to the standard volume of the bags (generally from 300 cc to 500 cc). Application times are particularly long, being able to vary, depending on the quantity of formulation and on the absorption capacity of the plant, from 5-10 minutes to 24 hours and more. The phytotherapeutic formulation is subjected to the conditionings of environmental and climatic factors, such as illumination and temperature, which can alter the solution and activity of the active ingredient in the formulation itself. Plants need to be monitored throughout the duration of the treatment: leaving unattended the bags containing the product may entail risks of damaging the bags themselves or the injection system, with the consequent dispersion of the formulation into the environment which determines a hygienic and health risk, as well as the hazard of the formulation coming in contact with persons, in particular in the urban environment and especially for children. Once again, the external environmental parameters and the characteristic parameters of the plant (in particular, the physiological ones) are not taken in due consideration in an automatic manner, leaving the decision on the appropriateness and on the conditions of the interventions completely up to the operator.

[0010] The aim of the present invention is to overcome the drawbacks described above, making available a device

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for arboreal plant endotherapy which allows first of all to inject the required dose of formulation in an automatic and exact manner.

[0011] It also allows to verify and control the dose to be applied in an extremely rigorous manner. It is important to stress that each dose to be administered, as well as the appropriateness of its administration, are correlated with the actual state of the plant, with the external climatic parameters and with those characteristic and intrinsic of the plant and of the environment in which it lives.

[0012] It is also possible to inject the doses with great caution and control, in terms of the pressure of the injected fluid, simultaneously with times that have been optimised to the best possible extend within the bounds of the protection of the treated plant.

[0013] The device further allows to pre-set interventions also on multiple plants at the same time, *ex-situ,* in a remote manner, by means of the intelligent apparatus with which it is provided. Treatments are also perfectly ecological and with no pollution or risk of dispersion of chemical materials, or of the workers' exposure thereto.

[0014] These aims and others beside, which shall become more readily apparent in the course of the description that follows, are reached, in accordance with the present invention by a device for arboreal plant endotherapy as described in the accompanying claims.

[0015] The invention is described in greater detail hereafter with the aid of the drawings, which represent an embodiment provided purely by way of non limiting example.

- Figure 1 shows a first schematic embodiment of the invention.
- Figure 2 shows a second schematic embodiment of the invention.
- Figure 3 shows the needle used by the invention, with three other constructive types thereof.
- Figure 4 shows a third schematic embodiment of the invention, with a displacement sensor removed, the better to highlight the other characteristics.
- Figure 5 shows a fourth schematic embodiment of the invention, with a displacement sensor removed, the better to highlight the other characteristics.
- Figure 6 shows a fifth embodiment of the invention, with a displacement sensor removed, the better to highlight the other characteristics.
- Figure 7 shows a version of the invention, by way of example, in portable form, in a sixth schematic embodiment.
- Figures 8 and 9 show two examples of functions for regulating the actuation of the piston as per the invention.
- Figure 10 shows a schematic flow chart of a procedure for determining the formulation dose.
- Figure 11 shows a schematic flow chart of a procedure for controlling the piston of the invention.
- Figure 12 shows a schematic flow chart of a variation of the above procedure for controlling the piston.
- Figure 13 shows, at the top, a schematic flow chart of a procedure for controlling the operating pressure on the formulation of the invention, and, at the bottom, a computing sub-procedure, applied to the flow chart as per Figure 12.

[0016] With reference to the figures, the subject endotherapy device comprises a hollow cylinder (1) provided with piston (2) and means (3) for actuating its motion, which can be any, for instance as shown in Figure 1, of the fluid-dynamic type, with double acting jack (31) and distributing valve (32), whereto the moving fluid is supplied.

[0017] The device further comprises at least an injection needle (41,42,43,44) and means (4) for connecting the needle (41,42,43,44) to the cylinder (1), to inject into the trunk of a plant at least a dose (VDOS(K)) of a phytotherapeutic formulation loaded in the cylinder (1).

[0018] In principle, the device is provided with an intelligent electronic apparatus (100) which comprises:

- at least a central processing unit (CPU), for the automatic intelligent and computerised control of the device;
- at least a keyboard (TT) for entering data manually and for managing the commands for the device, connected to the central unit (CPU);
- at least an analogue digital (A/D) converter connected to the central unit (CPU) and coupled to at least an output interface (II) to condition at least signals coming from a displacement sensor (5) to detect the position of the piston (2) in the cylinder;
- at least an output interface (IU) interposed between the central processing unit (CPU) and the means (3) for actuating the motion of the piston (2).

[0019] The central processing unit (CPU), which comprises at least a first data input/output port, in correspondence with at least an input/output peripheral (I/O) connected to the central unit (CPU) and which advantageously is connected to a display (DP), implements a program which essentially comprises:

- a procedure for determining the dose (VDOS(K)) of formulation to be administered to a plant;

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- a procedure for controlling the means (3) for actuating the movement of the piston (2) as a function of the dose (VDOS(K)) to be administered.

[0020] More specifically, with reference to Figure 10, the procedure for determining the dose (VDOS(K)) to be administered to the plant is a cyclical set repeated in sequence as many times as there are plants to be treated.

[0021] The procedure comprises:

- at least a block for reading at least data relating to species, state and characteristics of the plant, data relating at least to a formulation which can be administered to the plant, in response to an adversity (term that normally indicates parasitic or fungal aggressions or the like) or for its prevention, as well as environmental data;
- at least a first sub-procedure for computing the dose (VDOS(K)) of formulation to be administered to the plant according to the data read from the reading block.

[0022] Preferably the reading block also comprises detailed geographical data to locate the plant.

[0023] Advantageously, the data acquired by the reading block are subdivided at least into a first set of data acquired *ex-situ* prior to a current endotherapeutic treatment of the plant and into a second set of data acquired *in-situ* at least during the preparation of the endotherapeutic treatment.

[0024] To the first set of data belong at least:

- data about the species of the plant;
- data about the state of health of the plant;
- data about the number of years since the last pruning;
- data about the characteristics of the plant (which can comprise at least: circumference of the trunk and height of the plant, number of branches of the plant, as well as data about the endogenous state of the plant, such as temperature and lymphatic pressure);
- data about at least a formulation able to be administered to the plant;
- geographical data of the plant (comprising at least its nation of belonging as well as latitude and longitude);
- address of the plant.

To the second set of data belong at least:

- local climatic data of the plant (comprising at least ambient temperature, relative humidity, luminous irradiation);
- data about the characteristics of the plant;
- pedological conditions of the soil (including at least texture, pH, local composition of the soil, as well as water balance).

[0025] To obtain at least part of the second set of data (*in situ* data), it is advantageous for the device to comprise auxiliary sensors (SA), connected at least to a first data input/output port, in correspondence with at least an input/output peripheral (I/O) connected to the central processing unit (CPU). These auxiliary sensors can be slaved to peripheral detection units tasked with sending the signals to the input/output peripheral (I/O).

[0026] Given that the state of the plant comprises at least its health condition and number of years since its last pruning, said first sub-procedure for computing the formulation dose (VDOS(K)) provides for at least a computation according to the following formula:

$$VDOS(K)'DB*FC*Z*SF*AP,$$

where:

DB is the value of a base dose of concentrated formulation, evaluated as cc of formulation every 10 cm of trunk circumference measured at a height of 1m from the ground;
FC is a trunk circumference factor, identified as the measurement of the length of the circumference divided by 10 and correlating the dimensions of the plant to the dose to be administered;
Z is the volume of formulation, every 10 cm of trunk circumference, per unit of base dose of concentrated formulation;
SF is a coefficient related to the health conditions of the plant;
AP is a coefficient related to the number of years since the last pruning.

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[0027] If the computation procedure necessarily calls for the use both of *ex-situ* data and of updated *in-situ* data, the first computation sub-procedure is advantageously followed by the execution of a second sub-procedure for computing the formulation dose, which applies dosage correction terms, due to the subsequent measurement of required data. The sub-procedure provides for the use of the following formula:

$$VDOS(K)'VDOSt(K)+VDOSt(K)*FM+VDOSt(K)*FE+VDOSt(K)*FP,$$

where:
VDOSt(K) is the value of the dose already computed from the first procedure; FM, FE and FP are algebraic factors relating, respectively, to microclimate, endogenous state of the plant and pedological conditions.

[0028] It is interesting to observe that every parameter, value and data item relating to the computation of the dose (VDOS(K)) to be administered can be referred to and are characteristic of the national geographic area to which the plant belongs, said data being readable from a memory accessible from the central processing unit.

[0029] In the solution shown in Figure 2, the means (3) for actuating the motion of the piston (2) comprise:

- a stem (21) of the piston (2) shaped as a worm screw;
- a nut screw (6) engaged on the stem (21), coaxial to the cylinder (1), and free to rotate relative to the cylinder (1) itself, being engaged in a bearing (9) integral with the cylinder (1);
- at least a motor (7) (for instance a stepping electric motor (71)), for rotating the nut screw (6) relative to the cylinder (1) and transmit a rotation-translation motion to the stem (21) to translate the piston (2);
- at least an element (8) for guiding the movement of the stem (21) relative to the cylinder (1).

[0030] Note that, as shown in Figure 4, the cylinder (1) is removable, being sustained by a semi-open frame (34), able easily to allow both the placement and the removal of the cylinder (1). During the placement, the front end (35) of the cylinder can be engaged in a pin (36) to allow access to the product inside the cylinder. It is thereby possible to replace the cylinder in use with another cylinder of different diameter, to vary the maximum quantity of formulation able to be contained in the cylinder (1) itself. In this case, the means (3) for actuating the motion of the piston (2) comprise means (22) for rapid coupling with the piston (2), in order easily to associate to the actuator means (3) cylinders (1) having different sections with pistons (2) having different diameters while allowing the piston (2) to perform a reciprocating motion, useful when refilling the cylinder.

[0031] Alternatively, the cylinder (1) is disposable once the formulation contained therein is depleted. In this case, the piston (2), integral with the cylinder, is actuated by the actuator means (3) with only a thruster (33), which can be stem, not attached to the piston (2).

[0032] The cylinder (1) generally comprises an inlet (10) for the formulation and an outlet (12) of the formulation towards the needle (41, 42, 43, 44), with corresponding one-way valves (14, 16), one (14) for supplying the formulation, the other one (16) for injecting the formulation, mutually opposed.

[0033] So far, the description has dealt with "single-chamber" cylinders. For these and when it is knuwn with certainty that the formulation contained in the cylinder (1) is sufficient for at least a dose (VDOS), a procedure is provided to control the means (3) for actuating the motion of the piston (2) in the cylinder (1), shown in Figure 11 and which initially, in principle, comprises at least:

- a reading of the dose (VDOS) of formulation to be administered computed from the determination procedure;
- a detection of the initial position (Di) of the piston (2) through a reading of the signal of the displacement sensor (5);
- a computation of an initial volume (Vi) of the phytotherapeutic formulation contained in the cylinder (1), based on the initial position (Di) of the piston (2) and on the area (fc) of a section of the cylinder (1);

and, in succession:

- an instruction to activate the means (3) for actuating the motion of the piston (2), to move the piston (2) and inject the phytotherapeutic formulation into the plant, as well as a sequence of instructions for the control of the injection, cyclically repeated during the motion of the piston (2) if the injected volume (VI) of phytotherapeutic formulation is less than the dose (VDOS) to be administered, the sequence of instructions for controlling the injection comprising, in succession:
- detection of a current position (Dc(Tc)) of the piston (2) by reading the signal of the displacement sensor (5);
- computation of a current volume (Vc(Tc)) of phytotherapeutic formulation currently present in the cylinder (1) based on the current position (Dc(Tc)) of the piston (2) and on the area (fc) of the section of the cylinder (1);
- computation of the injected volume (VI) of phytotherapeutic formulation from the difference between initial volume (Vi) and current volume (Vc(Tc));
- comparison between the injected volume (VI) and the dose (VDOS) to be administered to verify whether the dose

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(VDOS) has been reached and, if the injected volume (VI) of formulation is at least equal to the dose (VDOS) of formulation to be administered and the dose (VDOS) has therefore been reached, the call up of a command for stopping the advance of the piston (2).

[0034] If instead there is no certainty that the volume of formulation contained in the cylinder, in the state in which it is, is sufficient for a dose (VDOS) or if one desires in any case to deplete any remaining formulation in the cylinder and/or inject several times the volume of formulation corresponding to the maximum capacity of the cylinder, the procedure for controlling the means (3) for actuating the motion of the piston (2) in the cylinder (1) initially further comprises an instruction for resetting to zero a service variable (VIOLD), the sequence of instructions for controlling the injection further comprising, in succession, following the computation of the injected volume (VI) of phytotherapeutic formulation:

- increasing the injected volume (VI) of phytotherapeutic formulation by the value of the service variable (VIOLD);
- verifying the value of the current volume (Vc(Tc)) and, if the current volume (Vc(Tc)) is substantially nil, executing a procedure for refilling the cylinder (1), updating the value of the service variable (VIOLD) to the value of the volume (VI) injected so far, as well as the value of the initial volume (Vi) to the value of the volume of the cylinder (VCIL) and returning to the sequence of instructions for controlling the injection before comparison of the injected volume (VI) with the dose (VDOS) to be administered. The refilling procedure can consist:
- of the manual replacement of the depleted cylinder;
- of returning formulation through the inlet (10), by automatic aspiration due to the inversion of the motion of the piston (2).

[0035] In particular, the device comprises at least a removable tank (23) of formulation connectable to the cylinder (1) by means of at least a one-way valve. The tank (23) can also be subdivided at least in a first and a second container (24, 25), containing respectively a concentrated formulation and a solvent and mutually connected by a mixing valve (26) located upstream of the connection to the cylinder (1). Moreover, advantageously, the tank (23) can be remote and connected to the cylinder (1) at least by means of a pipe (27). In this case, the tank can be shoulder-carried or fixed to a vehicle. Lastly, as shown in Figure 7, the tank can be mounted directly onto the cylinder (1), for instance with rapid coupling methods, and thus be replaceable, disposable, etc.

[0036] If the capability of providing for the continual injection of formulation is desired, in an embodiment of the invention, shown in Figure 5, the piston (2) divides the cylinder (1) into a first and a second chamber (18, 19).

[0037] They are respectively provided, each, with a first and a second inlet (10, 11) of the formulation, fitted with corresponding first and second one-way supply valve (14, 15).

[0038] They also comprise a first and a second outlet (12, 13) of the formulation towards the needle (41,42,43,44), provided with corresponding first and second one-way injection valve (16, 17). This is to load the formulation into the second chamber (19) while injecting the formulation into the plant from the first chamber (18), and to load the formulation into the first chamber (18) while injecting the formulation into the plant from the second chamber (19). As an alternative to this solution, it is possible, as shown in Figure 6, to use an auxiliary cylinder (1a) with related auxiliary piston (2a), in parallel and identical to the cylinder (1) operating, in synchronised fashion, in opposition and simultaneously to the piston (2) subject to the action of the actuator means (3).

[0039] The cylinder (1) and the auxiliary cylinder (1a) thereby define corresponding first and second chamber (18, 19) exactly operating as in the previous case. This allows, for both said solutions, an identical control procedures as specified below and as shown in Figure 12.

[0040] In particular, the procedure for the control of the means (3) for actuating the motion of the piston (2, 2a) in the cylinder (1, 1a) initially comprises at least:

- a reading of the dose (VDOS) of formulation to be administered computed from the determination procedure;
- a detection of the initial position (Di1, Di2) of the piston (2, 2a), by reading the signal of the displacement sensor (5);
- an instruction for setting to zero a service variable (VIOLD);
- a computation of a first and of a second initial volume (Vi1, Vi2) of the phytotherapeutic formulation contained respectively in the first and in the second chamber (18, 19), based on the initial position (Di1, Di2) of the piston (2, 2a) and of the area (fc) of a section of the cylinder (1, 1a);
- a comparison between the first and the second initial volume (Vi1, Vi2) and a transmission, through the output interface (IU), of an instruction to activate the actuator means (3) to initiate the injection of the formulation into the chamber from the more voluminous of the first and the second chamber (18, 19); and further comprises a sequence of injection control instructions, cyclically repeated during the motion of the piston (2, 2a) if the injected volume (VI) of phytotherapeutic formulation is smaller than the dose (VDOS) to be administered, the sequence of injection control instructions comprising, in succession:
- a sub-procedure (see Figure 13, bottom) for computing the values of the current volume (Vc1(Tc), Vc2(Tc)) of the

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chamber (18, 19) operating the injection and for computing the injected volume (VI) of formulation as the difference between initial volume (Vi1, Vi2) and current volume (Vc1(Tc), Vc2(Tc)) of the chamber (18, 19) operating the injection, the difference being incremented by the value of the service variable (VIOLD);

- comparison between the injected volume (VI) and the dose (VDOS) to be administered to verify whether the dose (VDOS) has been reached and, if the injected volume (VI) of formulation is substantially equal to the dose (VDOS) of formulation to be administered and the dose (VDOS) has therefore been reached, recall to a command for stopping the advance of the piston (2, 2a);
- verification of the value of the current volume (Vc1(Tc), Vc2(Tc)) of the chamber (18,19) operating the injection and, if the current volume (Vc1 (Tc),Vc2(Tc)) is substantially nil, execution of a procedure for inverting the action of the actuator means (3), updating the value of the service variable (VIOLD) to the value of the volume injected (VI) so far, and the value of the initial volume (Vi1, Vi2) of the chamber (18, 19) operating the injection to the value of the volume of the cylinder (VCIL) and returning to the sequence of control instructions.

[0041] Obviously also in the case of the "dual chamber" devices illustrated herein, all considerations made about tanks for the case of the "single chamber" devices apply.

[0042] It is very important to note that the subject device has at least a pressure sensor (20), connected to the central unit (CPU) through the analogue to digital converter (A/D) and the input interface (II) and having its pressure detection point in correspondence with the means (4) for connecting the needle (41,42,43,44) with the cylinder (1,1a) for measuring an operating pressure (P1c,PLc1,PLc2).

[0043] Both in the case of single chamber devices, and in that of dual chamber devices, as shown in Figures 11 and 12, the procedure to control the means (3) for actuating the motion of the piston (2, 2a) in the cylinder (1,1a) initially provides for a reading of a desired value (PMAX) of maximum operating pressure compatible with species, state and characteristics of the plant, with environmental data, and with the formulation to be injected.

[0044] The sequence of cyclically repeated instructions provides, after the comparison between injected volume (VI) and dose (VDOS) to be administered, a measurement of the current operating pressure (PLc, PLc1, PLc2) by means of the pressure sensor (20) and the execution of a sub-procedure for controlling and regulating the operating pressure, shown in the upper part of Figure 13.

[0045] This sub-procedure evaluates, based on a difference (DP) between the desired value (PMAX) of the maximum operating pressure and the current value of the operating pressure (PLc, PLc1, PLc2), a theoretical variation (VT) to be made to the force applied by the actuator means (3) on the piston (2, 2a) to correct said difference (DP) and imposes, through the output interface (IU), a corresponding real variation (VR) to the force applied by the actuator means (3), to maintain the value of the operating pressure (PLc,PLc1,PLc2) at a predetermined distance from the desired value (PMAX) of the maximum pressure. In this way the integrity of the plant and of its vascular system during the injection can be safeguarded while optimising injection times, because operating pressure is maintained constantly proximate to the maximum safely tolerable value.

[0046] Advantageously, the procedure for controlling and regulating the operating pressure maintains the current value of the operating pressure (PLc, PLc1, PLc2) constantly lower than the desired value (PMAX) of the maximum operating pressure, to allow an injection that is not harmful for the plant, avoiding operating pressures that are, even slightly, greater than the maximum tolerable one.

[0047] The theoretical variation (VT) can be computed based on a proportional-integral-derivative (PID) algorithm and the real variation (VR) can be correlated to the theoretical variation (VT) of a regulating function that simulates the real behaviour of the actuation means (3). In particular the regulating function can be linear at least in segments and, in this case, it can be a broken line. An example is provided in Figure 8, in which at the sides of a central dead zone (corresponding to small values of difference in (DP), for which it is not very important to correct), there are two linear areas in which it is possible to correct the behaviour of the actuator means (3) with continuity and responding proportionately to the required theoretical variation (VT). At the extremes, the regulating function shown in Figure 8 has constant segments, corresponding to saturation areas of the behaviour of the actuator means (3), in correspondence with which only a constant real variation (VR) can be applied, regardless of the computed theoretical variation (VT). This type of regulating function is particularly suitable in the case of actuator means (3) motorised with motors, for instance electric stepping motors. In this case the sub-procedure for controlling and regulating the operating pressure can impose, through the output interface (IU), the real variation to the force applied by the actuator means (3) by means of a continuous regulation of the velocity of the piston (2, 2a), at least in the linear segments of the regulating function itself.

[0048] The regulating function can also have at least a hysteresis in at least a segment (an example of such a type of regulating function is shown in Figure 9). This type of regulating function is particularly suited, for instance to the operation of fluid-dynamic actuator means (3) provided with simple on/off valves and, in general, of systems in which the speed of the piston (2, 2a) cannot be regulated with continuity. In these cases, the sub-procedure for controlling and regulating the operating pressure imposes, through the output interface (IU), the real variation (VR) to the force

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applied by the actuator means (3) through a succession of temporary stops and restarts of the actuator means (3) themselves. In this case, given the on/off behaviour of the system, the hysteretic regulating function of the type shown in Figure 9 allows to avoid too many sudden behaviour changes and annoying vibrations or mechanical resonance of the device.

[0049] Advantageously, the central processing unit (CPU) comprises a time counter and, both for single chamber devices and for dual chamber devices, as shown in Figures 11 and 12, the procedure to control the means (3) for actuating the motion of the piston (2, 2a) in the cylinder (1, 1a) initially provides for a reading of a desired value of maximum intervention time (TMAX), compatible with safeguarding the device and in any case to control excessively long processes.

[0050] After the instruction to start the means (3) for actuating the motion of the piston (2, 2a), the procedure calls for an initialisation (T0) of the time count (Tc) by the time counter; the sequence of instructions then provides for a comparison between the time (Tc) and the maximum intervention time (TMAX) and calls up a sub-procedure for stopping the device if the time interval (Tc) exceeds maximum intervention time (TMAX).

[0051] The needle (41) of the device can be normal and appropriately dimensioned. With reference to Figure 3, a needle (42) is externally threaded at least in correspondence with the tip for its screw-on engagement in a hole previously drilled in the trunk of the plant.

[0052] Another type of needle (43), at least in correspondence with the tip, externally presents at least two consecutive shaped elements (45), to grip the walls of a hole previously drilled in the trunk of a plant and determine at least a partial seal against the leakage of liquids from the trunk itself.

[0053] Yet another type of needle (44) has its tip closed to be inserted into the trunk by hammering, a cap (48) for protecting the needle (44) being provided, with no need for holes previously drilled in the trunk itself, the needle (44) further presenting, for a predetermined segment of its own body successive to the tip, radial openings (46) for injecting the formulation into the plant.

[0054] This needle (44) presents, at a predetermined distance from the tip and beyond the radial openings (46), a check element (47) of the trunk of the plant to determine the insertion depth of the needle (44) into the trunk.

[0055] It should be noted that the means (4) for connecting the needle (41, 42, 43, 44) and the cylinder (1) can be of the rapid coupling type. Alternatively, the means (4) for connecting the needle (41, 42, 43, 44) and the cylinder (1) comprise at least a flexible conduit (49) provided, at its ends, with attachment means for the cylinder (1) and for the needle (41, 42, 43, 44).

[0056] Advantageously, the device can be portable.

[0057] A solution of this kind, as shown in Figure 7, provides for the device to be enclosed in a case (28) which comprises gripping means (29) for the operator and control pushbuttons (30) associated to the case (28) and easily reachable by the hands of an operator when the device is in operation.

[0058] The invention thus conceived can be subject to numerous modifications and variations, without thereby departing from the scope of the inventive concept that characterises it.

[0059] Moreover, all components can be replaced by technically equivalent elements.

[0060] In practice all materials employed, as well as dimensions, may be any at all, depending on requirements.

Claims

1. A device for arboreal plant endotherapy, of the type comprising a hollow cylinder (1) provided with a piston (2), means (3) for actuating the motion of the piston (2), at least an injection needle (41,42,43,44), means (4) for connecting the needle (41,42,43,44) to the cylinder (1), to inject into the trunk of the plant at least a dose (VDOS (K)) of a phytotherapeutic formulation loaded into the cylinder (1), **characterised in that** it further comprises:

   - at least a central processing unit (CPU), for the automatic, intelligent, computerised control of the device;
   - at least a keyboard (TT) for manually inserting data and for managing the commands to the device, connected to the central unit (CPU);
   - at least an analogue digital converter (A/D) connected to the central unit (CPU) and coupled to at least an input interface (II) for conditioning at least signals coming from a displacement sensor (5) for detecting the position of the piston (2) into the cylinder (1);
   - at least an output interface (IU) interposed between the central processing unit (CPU) and the means (3) for actuating the motion of the piston (2); the central processing unit (CPU) implementing a program that comprises:
   - a procedure for determining the dose (VDOS(K)) of formulation to be administered to a plant;
   - a procedure to control the means (3) for actuating the motion of the piston (2) according to the dose (VDOS (K)) to be administered.

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2. A device as claimed in claim 1, **characterised in that** the central processing unit (CPU) comprises at least a first data input/output port, in correspondence with at least an input/output peripheral connected to the central unit (CPU).

3. A device as claimed in claim 1 o 2, **characterised in that** the procedure for determining the dose (VDOS(K)) of formulation to be administered to the plant is a cyclical body repeated in sequence as many times as there are plants to be treated.

4. A device as claimed in claim 1 o 2 o 3, **characterised in that** the procedure for determining the dose (VDOS(K)) of formulation to be administered to the plant comprises:

- at least a block for reading at least data related to species, state and characteristics of the plant, data related to at least a formulation able to be administered to the plant, as a function of its adversity or prevention thereto, as well as environmental data;
- at least a first sub-procedure for computing the dose (VDOS(K)) of formulation to be administered to the plant as a function of the data read from the reading block.

5. A device as claimed in claim 4, **characterised in that** the reading block further comprises detailed geographical data for locating the plant.

6. A device as claimed in claim 4 o 5 **characterised in that** the data acquired from the reading block are subdivided into at least a first set of data acquired *ex-situ* prior to a current endotherapeutic treatment of the plant and into a second set of data acquired *in-situ* at least during the preparation of the endotherapeutic treatment.

7. A device as claimed in claim 6, **characterised in that** to the first set of data belong at least:

- data about the species of the plant;
- data about the state of health of the plant;
- data about the number of years since the last pruning;
- data about the characteristics of the plant;
- data about at least a formulation able to be administered to the plant;
- geographical data of the plant;
- address of the plant;

to the second set of data belong at least:

- local climatic data of the plant;
- data about the characteristics of the plant;
- pedological conditions of the soil.

8. A device as claimed in claim 7, **characterised in that**:

- the characteristics of the plant comprise at least trunk circumference and plant height, number of branches of the plant, as well as data about the endogenous state of the plant;
- the geographical data of the plant comprise at least nation of belonging and latitude and longitude;
- local climatic data comprise at least ambient temperature, relative humidity, luminous irradiation;
- the pedological conditions of the soil comprise at least texture, pH, local soil composition, as well as water balance.

9. A device as claimed in any of the claims from 6 to 8, characterised in thatit comprises auxiliary sensors (SA), connected at least to a first data input/output port, in correspondence with at least an input/output peripheral (I/O) connected to the central processing unit (CPU), for measuring at least part of the second set of data.

10. A device as claimed in any of the claims from 4 to 6, **characterised in that** the state of the plant comprises at least its health condition and number of years since the last pruning and **in that** the first sub-procedure for computing the dose (VDOS(K)) of formulation provides for a computation according to the following formula:

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VDOS(K)'DB*FC*Z*SF*AP,

where:

DB is the value of a base dose of concentrated formulation, evaluated as cc of formulation every 10 cm of trunk circumference measured at a height of 1m from the ground;
FC is a trunk circumference factor, identified as the measurement of the length of the circumference divided by 10 and correlating the dimensions of the plant to the dose to be administered;
Z is the volume of formulation, every 10 cm of trunk circumference, per unit of base dose of concentrated formulation;
SF is a coefficient related to the health conditions of the plant;
AP is a coefficient related to the number of years since the last pruning.

11. A device as claimed in any of the claims from 7 to 9, **characterised in that**:

- the state of the plant comprises at least its health condition and number of years since the last pruning;
- the first sub-procedure for computing the dose of formulation provides for a computation according to the following formula:

VDOSt(K)'DB*FC*Z*SF*AP,

where:

VDOSt(K) indicates a preliminary dosage value;
DB is the value of a base dose of concentrated formulation, evaluated as cc,of formulation every 10 cm of trunk circumference measured at a height of 1m from the ground;
FC is a trunk circumference factor, identified as the measurement of the length of the circumference divided by 10 and correlating the dimensions of the plant to the dose to be administered;
Z is the volume of formulation, every 10 cm of trunk circumference, per unit of base dose of concentrated formulation;
SF is a coefficient related to the health conditions of the plant;
AP is a coefficient related to the number of years since the last pruning;

the first computation sub-procedure being followed by the execution of a second sub-procedure for computing the dose of formulation, which applies terms for correcting the dosage at least according to the following formula:

VDOS(K)'VDOSt(K)+VDOSt(K)*FM+VDOSt(K)*FE+VDOSt(K)*FP,

where: FM, FE and FP are algebraic factors relating, respectively, to microclimate, endogenous state of the plant and pedological conditions.

12. A device as claimed in claim 10 or 11, **characterised in that** every parameter, value and data item relating to the computation of the dose (VDOS(K)) to be administered can be referred to and are characteristic of the national geographic area to which the plant belongs, said data being readable from a memory accessible from the central processing unit.

13. A device as claimed in any of the previous claims, **characterised in that** the means (3) for actuating the motion of the piston (2) comprise:

- a stem (21) of the piston (2) shaped as a worm screw;
- a nut screw (6) engaged on the stem (21), coaxial to the cylinder (1), and free to rotate relative to the cylinder (1) itself;
- at least a motor (7) for rotating the nut screw (6) relative to the cylinder (1) and transmit a rotation-translation motion to the stem (21) to translate the piston (2);
- at least an element (8) for guiding the movement of the stem (21) relative to the cylinder (1).

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14. A device as claimed in any of the previous claims, **characterised in that** the means (3) for actuating the motion of the piston comprise at least a stepping motor (71).

15. A device as claimed in any of the previous claims, **characterised in that** the cylinder is removable.

16. A device as claimed in claim 15, **characterised in that** the cylinder (1) is disposable once the formulation contained therein is depleted.

17. A device as claimed in claim 15, **characterised in that** the means (3) for actuating the motion of the piston (2) comprise means (22) for rapid coupling with the piston (2), in order to associate to the actuator means (3) cylinders (1) having different sections with pistons (2) having different diameters while allowing the piston (2) to perform a reciprocating motion.

18. A device as claimed in any of the previous claims, **characterised in that** the cylinder (1) comprises an inlet (10) for the formulation and an outlet (12) of the formulation towards the needle (41, 42, 43, 44), with corresponding one-way valves (14, 16), one (14) for supplying the formulation, the other one (16) for injecting the formulation, mutually opposed.

19. A device as claimed in any of the previous claims, **characterised in that** the procedure for controlling the means (3) for actuating the motion of the piston (2) in the cylinder (1) initially comprises at least:

- a reading of the dose (VDOS) of formulation to be administered computed from the determination procedure;
- a detection of the initial position (Di) of the piston (2) through a reading of the signal of the displacement sensor (5);
- a computation of an initial volume (Vi) of the phytotherapeutic formulation contained in the cylinder (1), based on the initial position (Di) of the piston (2) and on the area (fc) of a section of the cylinder (1);

and, in succession:

- an instruction to activate the means (3) for actuating the motion of the piston (2), to move the piston (2) and inject the phytotherapeutic formulation into the plant, as well as a sequence of instructions for the control of the injection, cyclically repeated during the motion of the piston (2) if the injected volume (VI) of phytotherapeutic formulation is less than the dose (VDOS) to be administered, the sequence of instructions for controlling the injection comprising, in succession:
- detection of a current position (Dc(Tc)) of the piston (2) by reading the signal of the displacement sensor (5);
- computation of a current volume (Vc(Tc)) of phytotherapeutic formulation currently present in the cylinder (1) based on the current position (Dc(Tc)) of the piston (2) and on the area (fc) of the section of the cylinder (1);
- computation of the injected volume (VI) of phytotherapeutic formulation from the difference between initial volume (Vi) and current volume (Vc(Tc));
- comparison between the injected volume (VI) and the dose (VDOS) to be administered to verify whether the dose (VDOS) has been reached and, if the injected volume (VI) of formulation is at least equal to the dose (VDOS) of formulation to be administered and the dose (VDOS) has therefore been reached, the call up of a command for stopping the advance of the piston (2).

20. A device as claimed in claim 19, **characterised in that** the procedure for controlling the means (3) for actuating the motion of the piston (2) in the cylinder (1) initially further comprises an instruction for resetting to zero a service variable (VIOLD), the sequence of instructions for controlling the injection further comprising, in succession, following the computation of the injected volume (VI) of phytotherapeutic formulation:

- increasing the injected volume (VI) of phytotherapeutic formulation by the value of the service variable (VIOLD);
- verifying the value of the current volume (Vc(Tc)) and, if the current volume (Vc(Tc)) is substantially nil, executing a procedure for refilling the cylinder (1), updating the value of the service variable (VIOLD) to the value of the volume (VI) injected so far, as well as the value of the initial volume (Vi) to the value of the volume of the cylinder (VCIL) and returning to the sequence of instructions for controlling the injection before comparison of the injected volume (VI) with the dose (VDOS) to be administered.

21. A device as claimed in any of the claims from 1 to 15, **characterised in that** the piston (2) divides the cylinder (1) into a first and a second chamber (18, 19) each provided, respectively, with a first and a second inlet (10, 11) of

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the formulation provided with corresponding first and second one-way supply valve (14, 15), as well as with a first and a second outlet (12, 13) of the formulation towards the needle (41, 42, 43, 44) provided with corresponding first and second one-way injection valve (16, 17), the first and the second one-way supply valve (14, 15) acting in opposition to each other and, respectively, to the corresponding first and second injection one-way valve (16, 17), to load the formulation in the second chamber (19) whilst injecting the formulation into the plant from the first chamber (18), as well as to load the formulation in the first chamber (18) whilst injecting the formulation into the plant from the second chamber (19).

22. A device as claimed in any of the claims from 1 to 15, **characterised in that** it comprises an auxiliary cylinder (1a), in parallel and identical to the cylinder (1), fitted with related auxiliary piston (2a), operating, in synchronised fashion, in opposition and simultaneously to the piston (2) subject to the action of the actuator means (3), the cylinder (1) and the auxiliary cylinder (1a) defining corresponding first and second chamber (18, 19), each provided, respectively, with a first and a second inlet (10, 11) of the formulation fitted with corresponding first and second one-way supply valve (14, 15), as well as a first and a second outlet (12, 13) of the formulation towards the needle (41, 42, 43, 44) fitted with corresponding first and second one-way injection valve (16, 17), the first and the second one-way supply valve (14, 15) acting in mutual opposition and, respectively, in opposition to the corresponding first and second one-way injection valve (16, 17), to load the formulation into the second chamber (19) whilst injecting the formulation into the plant from the first chamber (18), as well as to load the formulation in the first chamber (18) whilst injecting the formulation into the plant from the second chamber (19).

23. A device as claimed in claim 21 or 22, **characterised in that** the procedure for controlling the means (3) for actuating the motion of the piston (2, 2a) in the cylinder (1, 1a) initially comprises at least:

- a reading of the dose (VDOS) of formulation to be administered computed from the determination procedure;
- a detection of the initial position (Di) of the piston (2, 2a) through a reading of the signal of the displacement sensor (5);
- a computation of an initial volume (Vi) of the phytotherapeutic formulation contained in the cylinder (1, 1a), based on the initial position (Di) of the piston (2, 2a) and on the area (fc) of a section of the cylinder (1, 1a);
- an instruction to set to zero a service variable (VIOLD);
- a computation of a first and of a second initial volume (Vi1, Vi2) of the phytotherapeutic formulation contained respectively in the first and in the second chamber (18, 19), based on the initial position (Di1, Di2) of the piston (2, 2a) and of the area (fc) of a section of the cylinder (1, 1a);
- a comparison between the first and the second initial volume (Vi1, Vi2) and a transmission, through the output interface (IU), of an instruction to activate the actuator means (3) to initiate the injection of the formulation into the chamber from the more voluminous of the first and the second chamber (18, 19); and further comprises a sequence of injection control instructions, cyclically repeated during the motion of the piston (2, 2a) if the injected volume (VI) of phytotherapeutic formulation is smaller than the dose (VDOS) to be administered, the sequence of injection control instructions comprising, in succession:
- a sub-procedure (see Figure 13, bottom) for computing the values of the current volume (Vc1(Tc), Vc2(Tc)) of the chamber (18, 19) operating the injection and for computing the injected volume (VI) of formulation as the difference between initial volume (Vi1, Vi2) and current volume (Vc1 (Tc), Vc2(Tc)) of the chamber (18, 19) operating the injection, the difference being incremented by the value of the service variable (VIOLD);
- comparison between the injected volume (VI) and the dose (VDOS) to be administered to verify whether the dose (VDOS) has been reached and, if the injected volume (VI) of formulation is substantially equal to the dose (VDOS) of formulation to be administered and the dose (VDOS) has therefore been reached, recall to a command for stopping the advance of the piston (2, 2a);
- verification of the value of the current volume (Vc1(Tc),Vc2(Tc)) of the chamber (18,19) operating the injection and, if the current volume (Vc1(Tc),Vc2(Tc)) is substantially nil, execution of a procedure for inverting the action of the actuator means (3), updating the value of the service variable (VIOLD) to the value of the volume injected (VI) so far, and the value of the initial volume (Vi1, Vi2) of the chamber (18, 19) operating the injection to the value of the volume of the cylinder (VCIL) and returning to the sequence of control instructions.

24. A device as claimed in claim 19 or 20 or 23, **characterised in that**:

- it comprises at least a pressure sensor, connected to the central unit (CPU) through the analogue digital converter (A/D) and the input interface (II) and having its pressure detection point in correspondence with the means (4) for connecting the needle (41, 42, 43, 44) to the cylinder (1, 1a) for measuring an operating pressure (PLc,PLc1,PLc2);

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- the procedure to control the means (3) for actuating the motion of the piston (2, 2a) in the cylinder (1, 1a) initially provides for a reading of the desired value (PMAX) of maximum operating pressure compatible with the species, state and characteristics of the plant, with environmental data, and with the formulation to be injected;
- the sequence of cyclically repeated instructions provides, after the comparison between the injected volume (VI) and the dose to be administered (VDOS), a measurement of current operating pressure (PLc, PLc1, PLc2) by means of the pressure sensor (20) and the execution of a sub-procedure for controlling and regulating the operating pressure which evaluates, based on a difference (DP) between the desired value of the maximum operating pressure (PMAX) and the current value of the operating pressure (PLc, PLc1, PLc2), a theoretical variation (VT) to be made to the force applied by the actuator means (3) on the piston (2, 2a) to correct said difference (DP) and imposes, through the output interface (IU), a corresponding real variation (VR) to the force applied by the actuator means (3), to maintain the value of the operating pressure (PLc, PLc1,PLc2) to a predetermined distance from the desired value (PMAX) of the maximum pressure.

25. A device as claimed in claim 24, **characterised in that** the procedure for controlling and regulating the operating pressure maintains the current value of the operating pressure (PLc, PLc1, PLc2) constantly lower than the desired value of the maximum operating pressure (PMAX).

26. A device as claimed in claim 24 or 25, **characterised in that** the theoretical variation (VT) is computed based on a proportional-integral-derivative (PID) algorithm and **in that** the real variation (VR) is correlated to the theoretical variation (VT) of a regulating function that simulates the real behaviour of the actuation means (3).

27. A device as claimed in claim 26, **characterised in that** the regulating function is linear at least in segments.

28. A device as claimed in claim 27, **characterised in that** the regulating function is a broken line.

29. A device as claimed in claim 27 or 28, **characterised in that** the regulating function ha at least a hysteresis in at least a segment.

30. A device as claimed in any of the claims from 24 to 29, **characterised in that** the sub-procedure for controlling and regulating the operating pressure imposes, through the output interface (IU), the real variation (VR) to the force applied by the actuator means (3) through a succession of temporary stops and restarts of the actuator means (3) themselves.

31. A device as claimed in any of the claims from 24 to 29, **characterised in that** the sub-procedure for controlling and regulating the operating pressure imposes, through the output interface (IU), the real variation (VR) to the force applied by the actuator means (3) by means of a continuous adjustment of the speed of the piston (2, 2a).

32. A device as claimed in claim 19 or 20 or 23, **characterised in that**:

- the central processing unit (CPU) comprises a time counter;
- the procedure to control the means (3) for actuating the motion of the piston (2,2a) in the cylinder (1,1a) initially calls for a reading of a desired value of maximum intervention time (TMAX);
- the procedure for controlling the means (3) for actuating the motion of the piston (2,2a) in the cylinder (1,1a) provides, subsequent to the instruction to start the means (3) for actuating the motion of the piston (2,2a), an initialisation (TO) of the time count (Tc) by the time counter;

the sequence of instructions providing for a comparison of the time (Tc) with the maximum intervention time (TMAX) and calling up a sub-procedure for stopping the device if the time interval (Tc) exceeds the maximum intervention time (TMAX).

33. A device as claimed in any of the previous claims **characterised in that** the needle (42) is externally threaded at least in correspondence with the tip for the screw-in engagement into a hole previously obtained in the trunk of the plant.

34. A device as claimed in any of the claims from 1 to 33 **characterised in that** the needle (43), at least in correspondence with the tip, externally presents at least two consecutive shaped elements (45), for gripping the walls of a hole previously obtained in the trunk of the plant and determine at least a partial seal against the leakage of liquids

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from the trunk itself.

35. A device as claimed in any of the claims from 1 to 33 **characterised in that** the needle (44) has is tip closed to be able to be inserted into the trunk by hammering, a cap (48) being provided for protecting the needle (44), with no need for holes previously obtained in the trunk itself, the needle (44) further presenting, for a predetermined segment of its own body successive to the tip, radial openings (46) for injecting the formulation into the plant.

36. A device as claimed in claim 35, **characterised in that** the needle (44) presents, at a predetermined distance from the tip and beyond the radial openings (46) and element (47) for checking the trunk of the plant to determine the insertion depth of the needle (44) into the trunk.

37. A device as claimed in any of the previous claims, **characterised in that** the connection means (4) between the needle (41, 42, 43, 44) and the cylinder (1) provide for rapid coupling.

38. A device as claimed in any of the previous claims, **characterised in that** connection means (4) between the needle (41, 42, 43, 44) and the cylinder (1) comprise at least a flexible conduit (49) provided, at its ends, with attachment means for the cylinder (1) and for the needle (41, 42, 43, 44).

39. A device as claimed in any of the previous claims, **characterised in that** it comprises at least a tank (23) of formulation removably connectable to the cylinder (1) through at least a one-way valve.

40. A device as claimed in claim 39, **characterised in that** the tank (23) is subdivided into at least a first and a second container (24, 25), containing respectively a concentrated formulation and a solvent and mutually connected by a mixing valve (26) located upstream of the connection to the cylinder (1).

41. A device as claimed in claim 39 or 40, **characterised in that** the tank (23) is remote and connected to the cylinder (1) at least through a pipe (27).

42. A device as claimed in any of the previous claims **characterised in that** it is portable.

43. A device as claimed in claim 42, **characterised in that** it is enclosed in a case (28) which comprises gripping means (29) for the operator and control pushbuttons (30) associated to the case (28) and easily reachable by the hands of an operator when the device is in operation.

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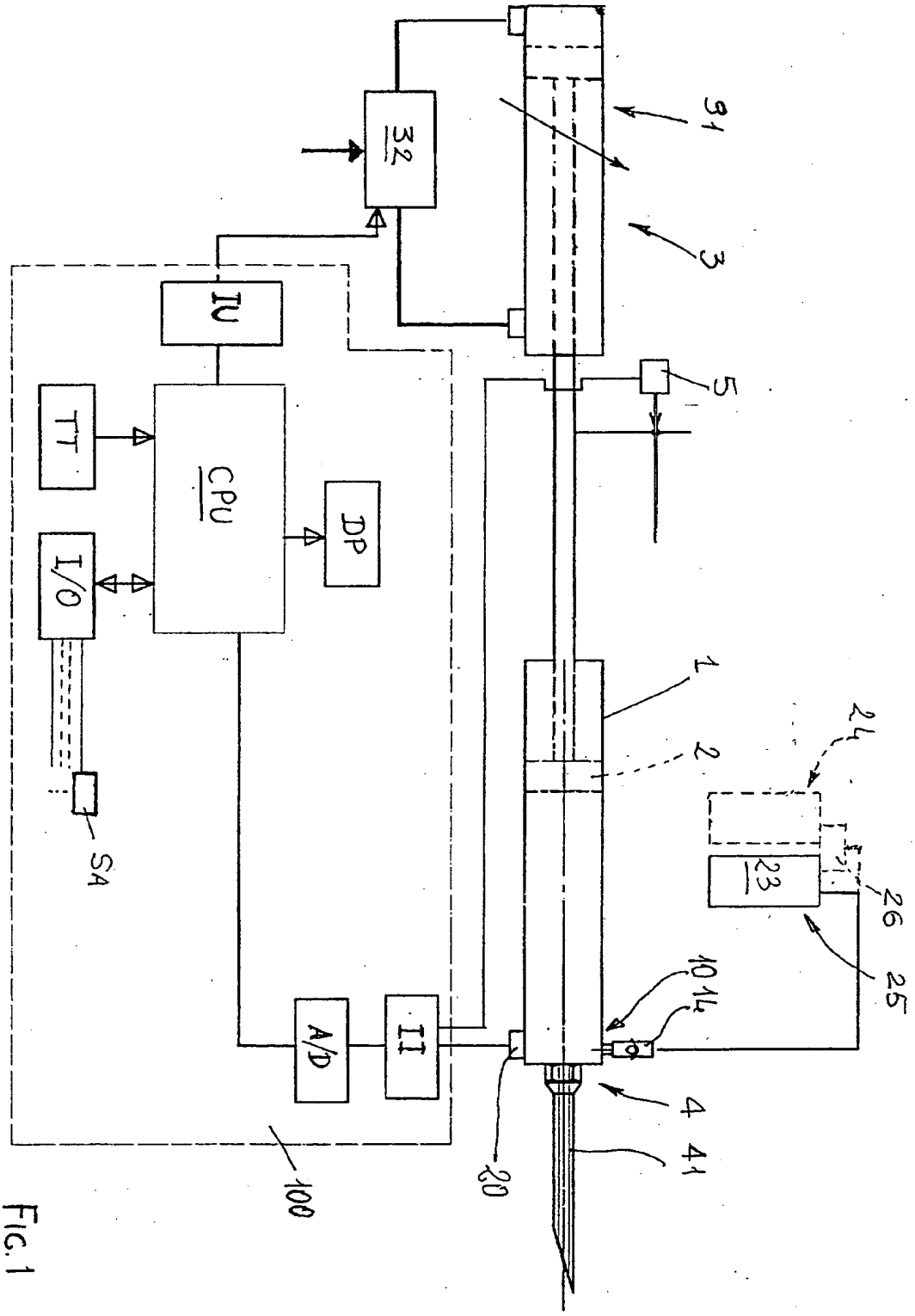

Fig. 1

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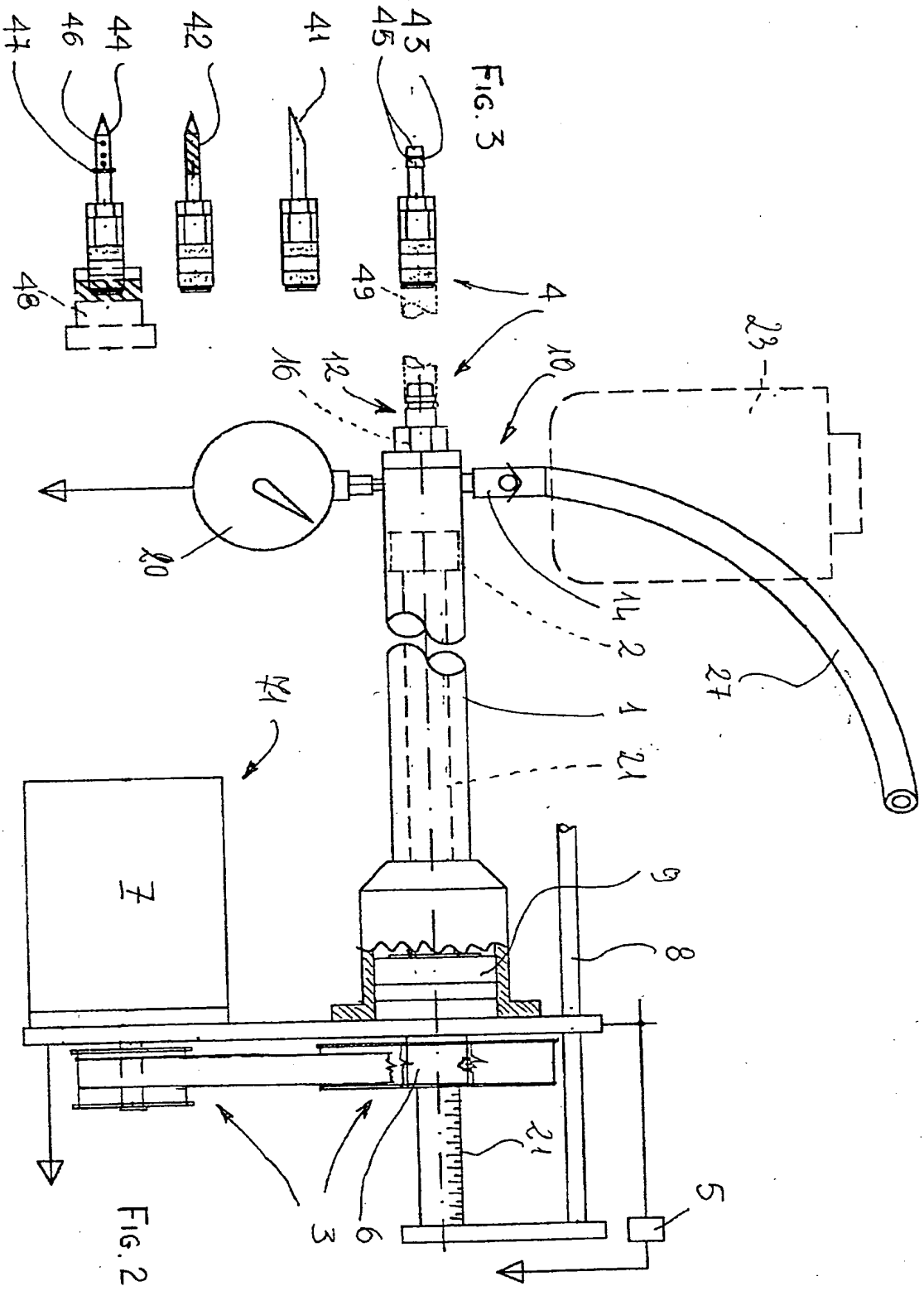

FIG. 3

FIG. 2

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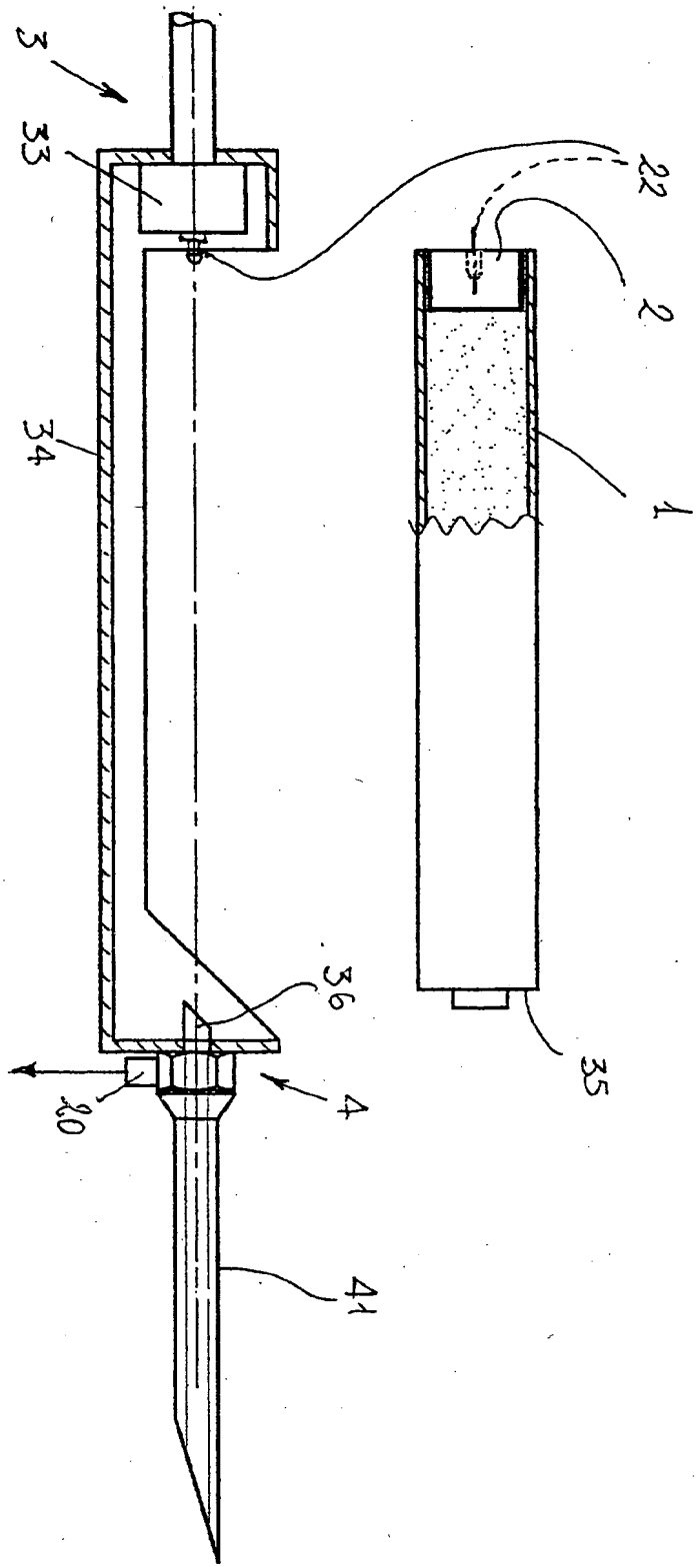

FIG. 4

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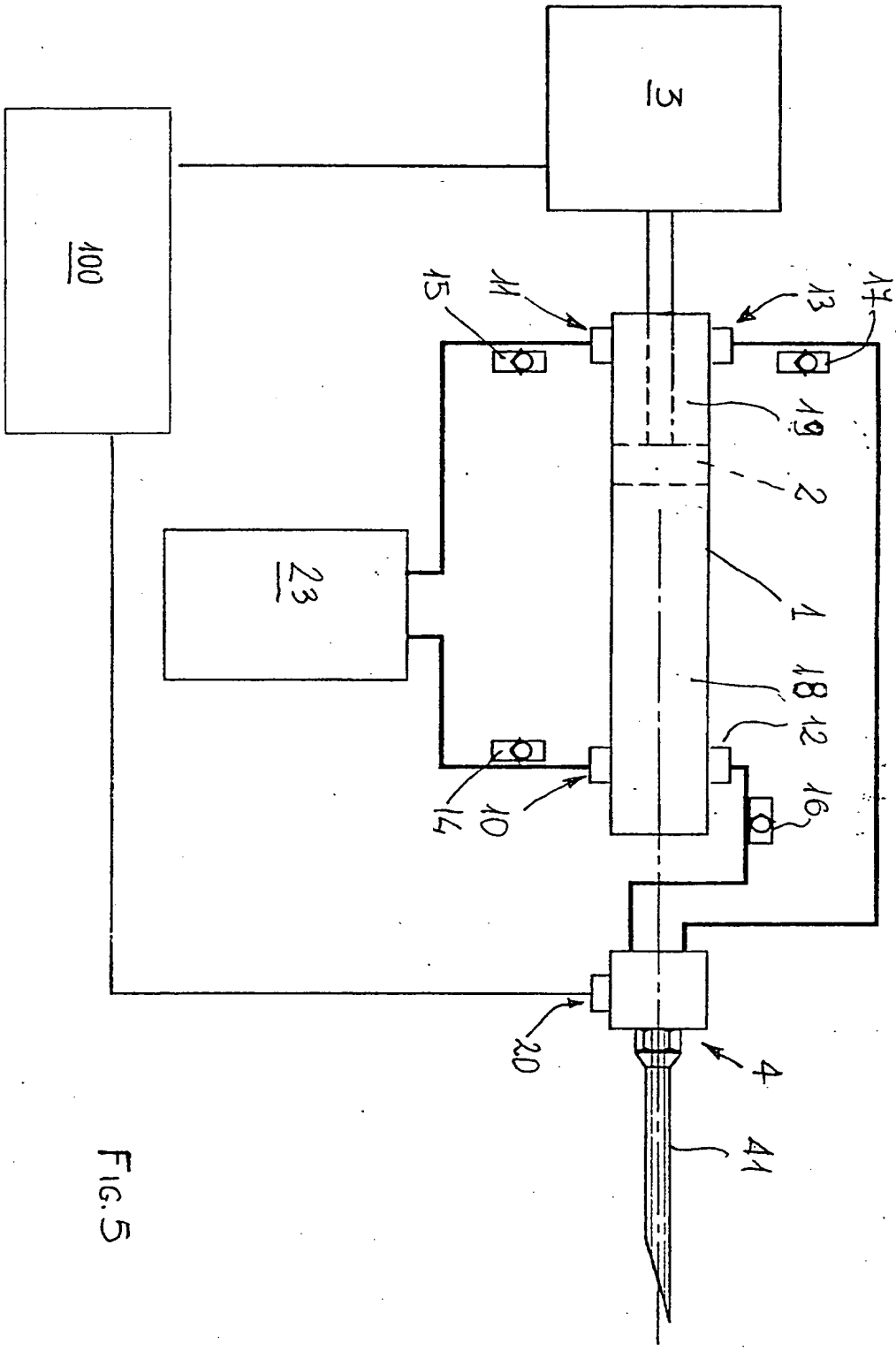

FIG. 5

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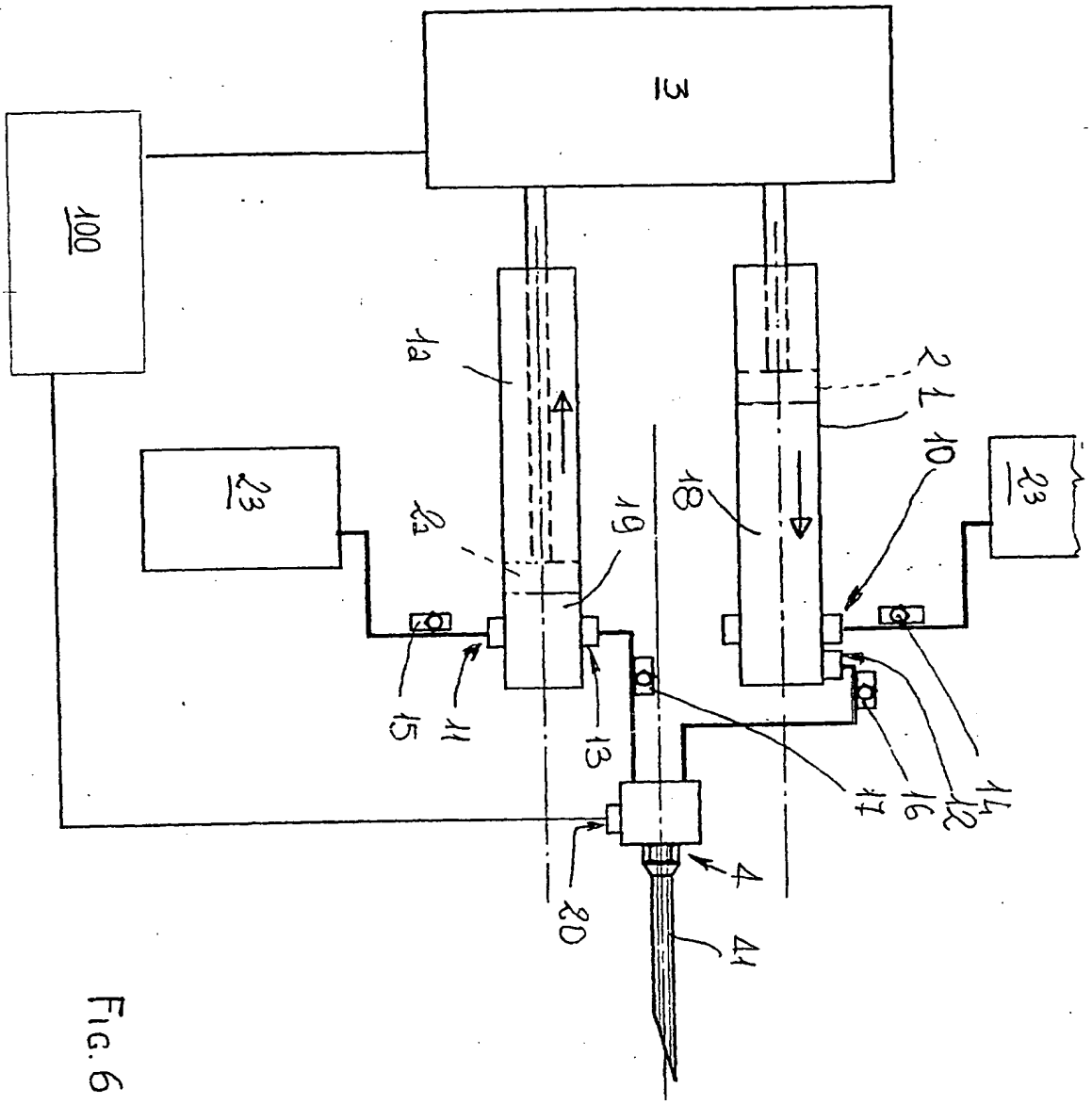

FIG. 6

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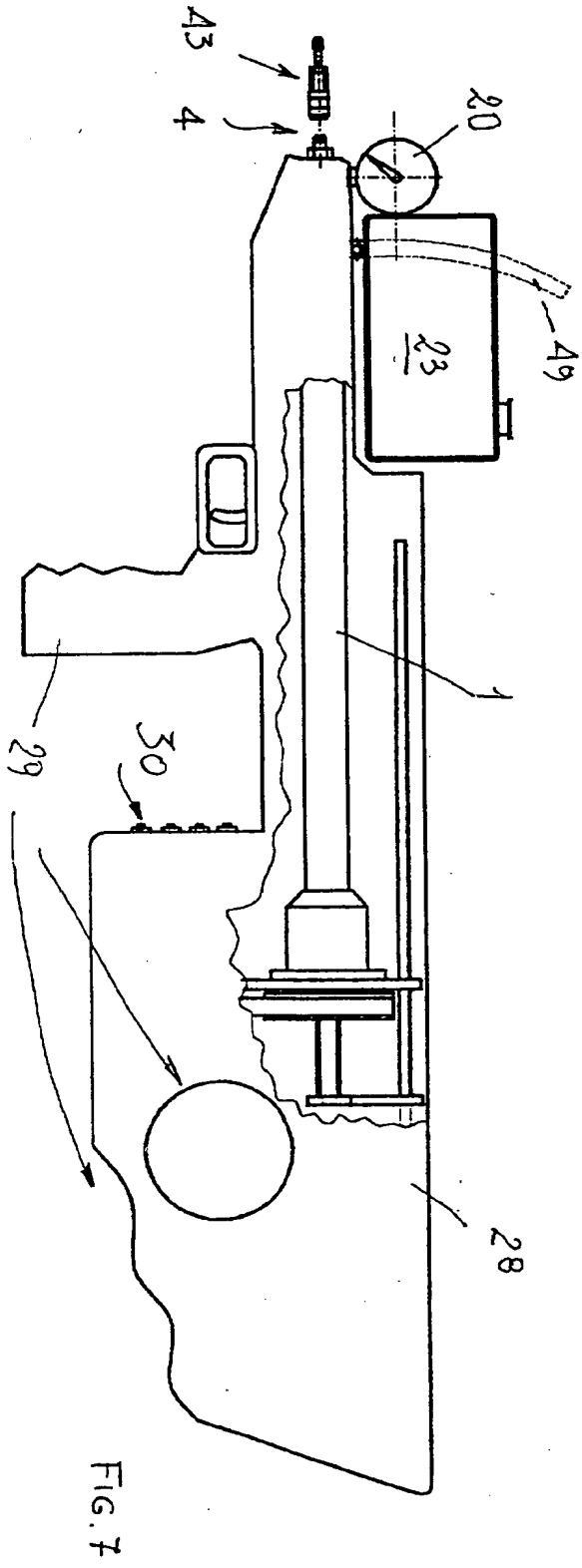

FIG. 7

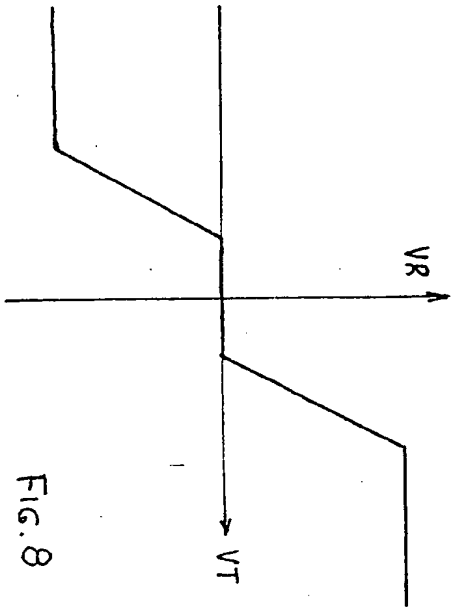

FIG. 8

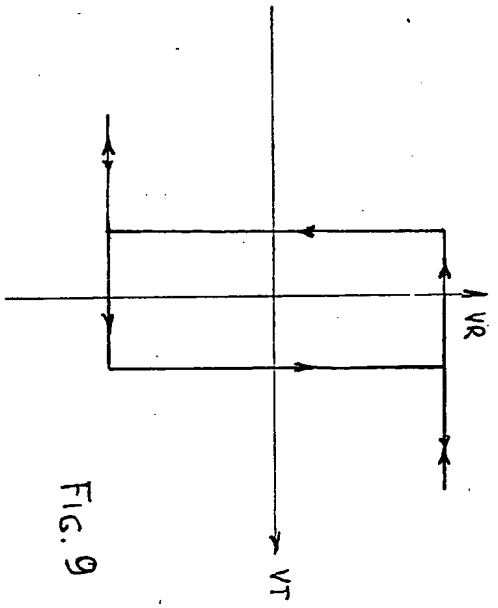

FIG. 9

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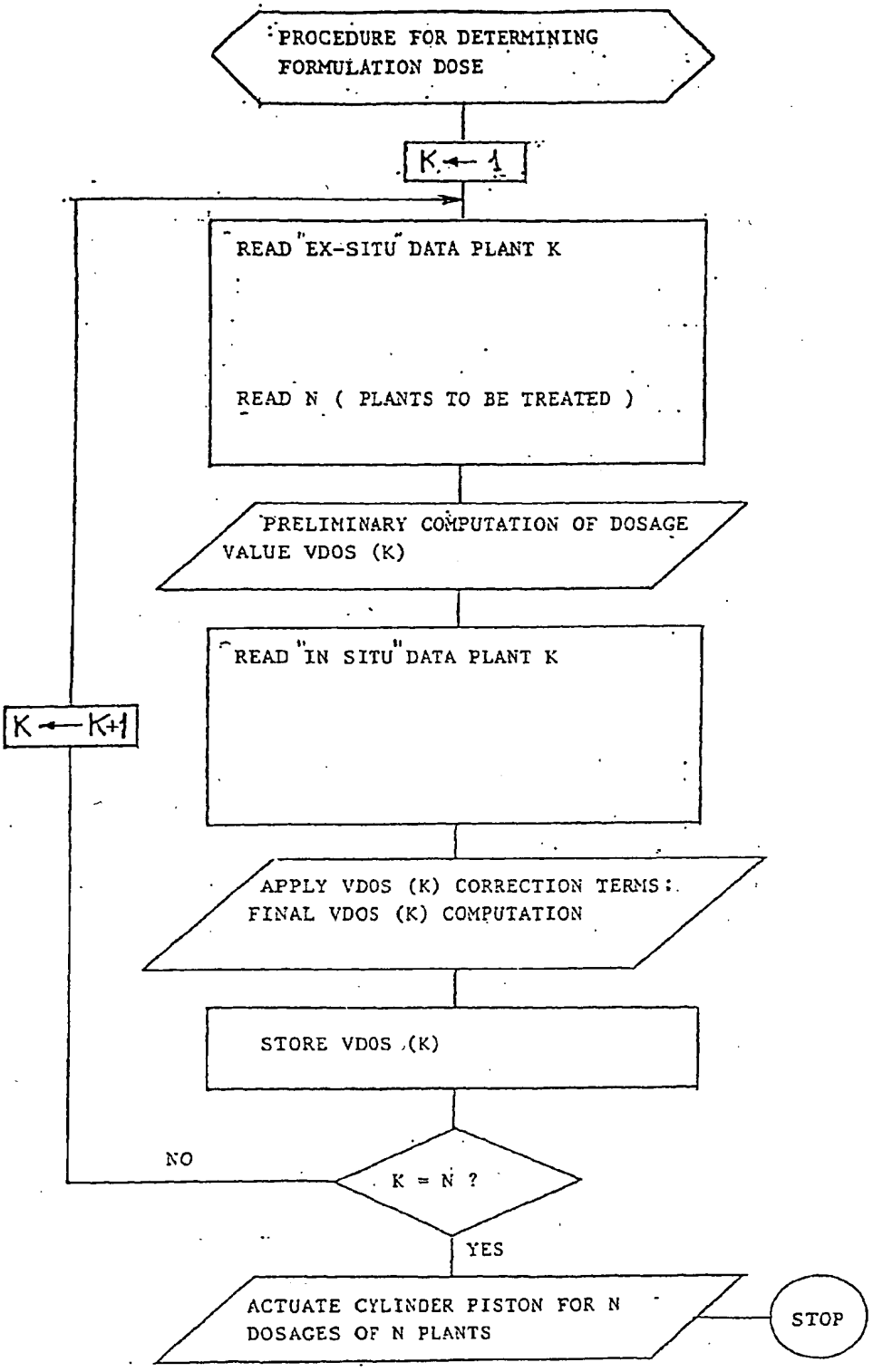

FIG.10

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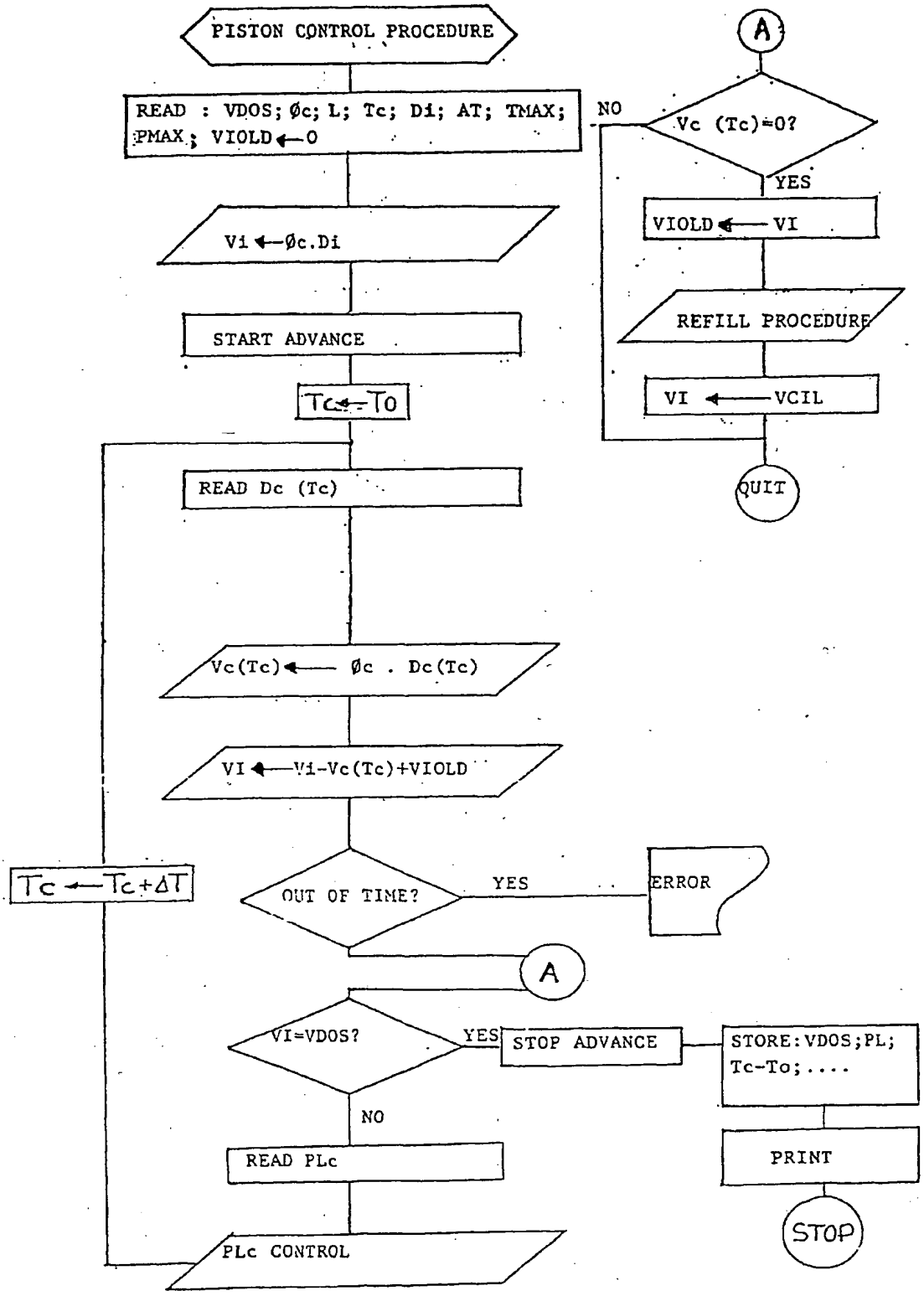

FIG. 11

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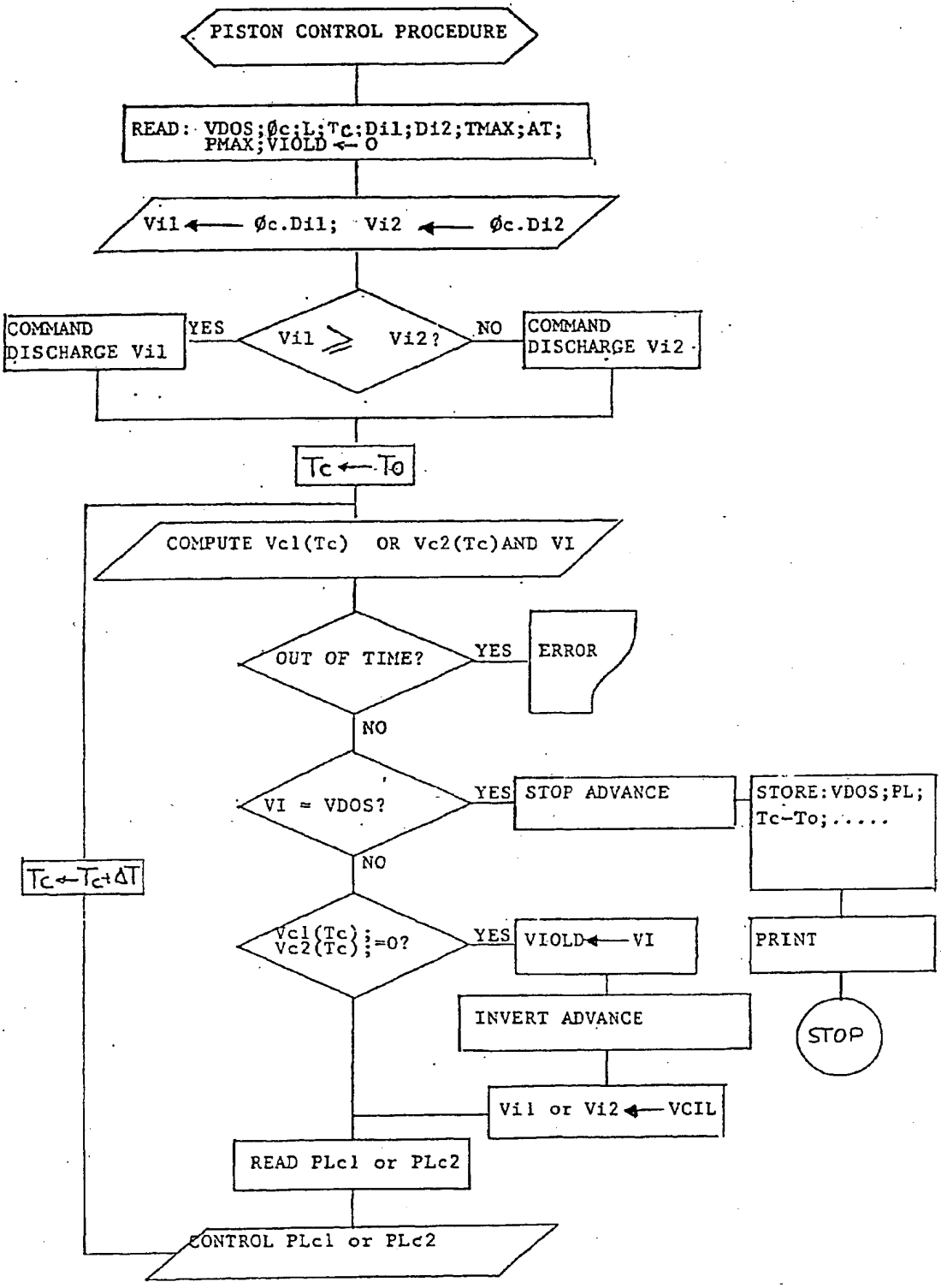

FIG.12

BNSDOCID: <EP___1205103A1_I_>

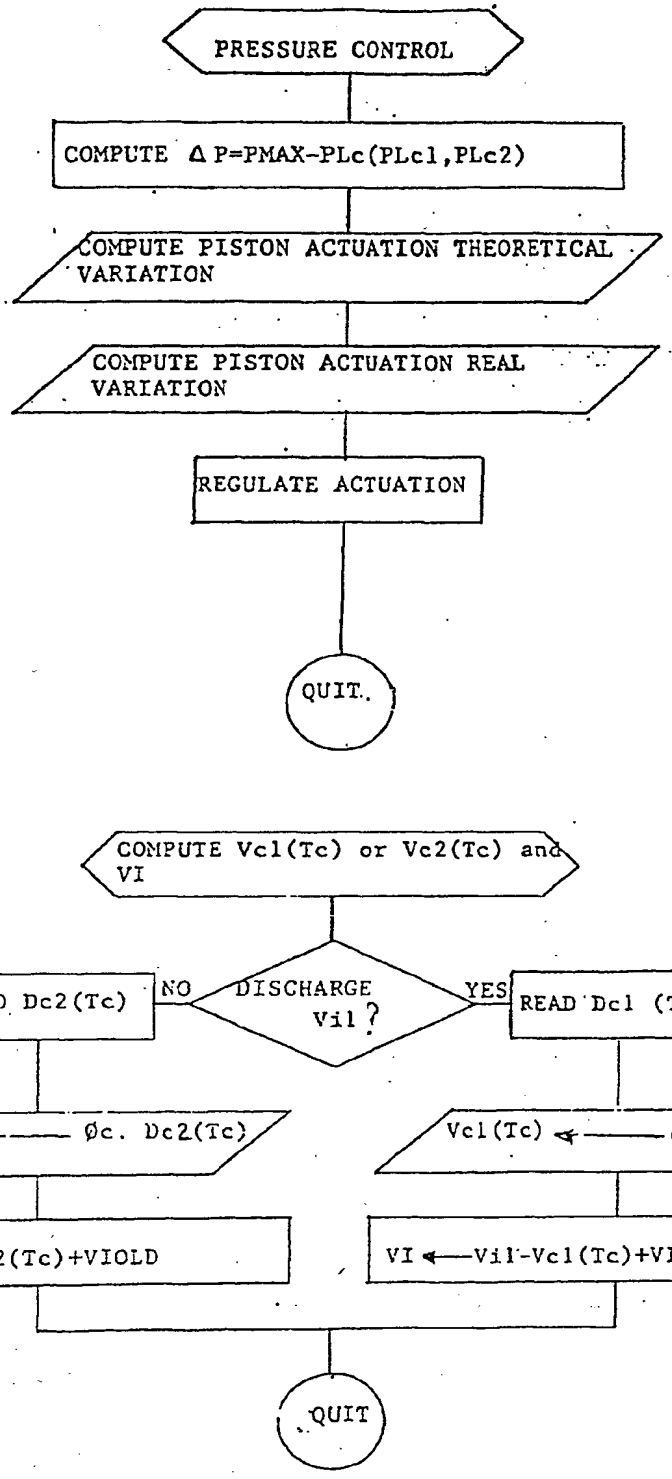

FIG.13

BNSDOCID: <EP___1205103A1_I_>

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EUROPEAN SEARCH REPORT

Application Number
EP 00 83 0738

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Place of search	Date of completion of the search	Examiner
THE HAGUE	17 April 2001	Merckx, A

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